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Use of scientific evidence to inform environmental health policies and governance strategies at the local level

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ABSTRACT

A major public health challenge facing local administrations is reducing the preventable burden of non-communicable diseases making cities more resilient against environmental threats. The objective of this work was to conduct a synthesis of scientific evidence relating to the local context and implement a translational process to support the Department of the Environment in order to improve integration with concurrent policy sectors to urban health and sustainability goals. The first phase reviewed the studies on the association between environmental risk factors and human health and on the contamination levels of the environmental matrices; the second phase synthesised the data in key messages according to the concerns formulated with the collaboration of the Environmental Department. A total of 31 studies were assessed: 21 investigated environmental risk factors, and 9 measured the presence of pollutants in the environmental matrices. The findings identified air and noise pollution as the most important threats associated with respiratory and cardiovascular diseases, together with significant contamination levels of the urban environment from microplastics and hydrocarbons. Based on the review findings, a layman's report for the City Council and the citizens, explicitly addressing emerging issues, was made publicly accessible. A lack of specific, updated and exchangeable data for city health profiling in a deteriorated environmental context represented the main barrier to a resilient community. The suggested recommendation for the local administration was to adopt an environmental policy integration framework to strengthen the monitoring of the impact on citizens' health.

1. Introduction

Environmental health laws and policies address the complex relationship between the environment and health, specifically how pollution and climate change can affect human health and what strategies can be developed to reduce the risk for the population and individuals and safeguard the environment (Jabareen, 2013). The role of science is crucial to inform policy-makers and provide knowledge to improve their understanding and help them to identify strategic options for reducing environmental risks (Evidence-Informed Policymaking, 2023). Accurate and up-to-date scientific and technical data are fundamental for developing public policies and scientists are called to facilitate their transfer to policy makers and practitioners. As cities concentrate populations and high levels of human activities, they often face dramatic problems of pollution and related health risks (Cities and the Environment, 2023). Urban health is a growing priority for the World Health Organization (WHO), which supports the strengthening of the evidence base to allow policy-makers to take informed decisions when addressing health risks (WHO, 2023). Sustainability and societal resilience within a complex regulatory system require assembling multiple types of evidence to anticipate and detect environmental and health risks at an early stage (Foellmer et al., 2022).

There is now a large body of research evidence showing that the quality of life in cities is associated with urban characteristics (Węziak-Białowolska, 2016). Specifically, urban pollution may increase the main types of non-communicable diseases (NCDs, also known as chronic diseases), such as cardiovascular diseases, cancer, diabetes and chronic obstructive respiratory diseases (Howse et al., 2021). For this reason, the demand for a good local environment is becoming increasingly loud and the improvement of the quality of the urban environment is having a growing political impact (European Commission, 2010). In this context, new models of urban governance and planning are strongly encouraged by international agencies like the WHO which promotes health and equity in cities to reduce the burden of NCDs (Leeuw et al., 2014). In addition, efficient urban planning and design can contribute to the decrease of greenhouse gas emissions and plays a key role in climate

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change mitigation and adaptation and allows for sustainable development goals (SDGs) (Keith et al., 2023). The United Nations has set a goal to make cities inclusive, safe, resilient and sustainable (United Nations Sustainable Development Action, 2015).

It is important to have a knowledge transfer between the scientific community and the policy-makers to ensure that the urban policies, plans, laws, and regulations are appropriate for the local conditions and contribute to creating healthier and more sustainable cities (Giles-Corti et al., 2016). Specifically, the use of suitable health and wellbeing indicators to support decision-making in local urban planning can positively influence cities' sustainability (Badland et al., 2014; Pineo et al., 2020). Mainly, the quantitative assessments can provide powerful data, like the estimates of annual preventable morbidity and disability-adjusted life-years, in compliance with international exposure guidelines for air pollution, noise, heat, and access to green spaces (Ramirez-Rubio et al., 2019). More recently, also the use of systematic reviews by policy-makers is increasing as a facilitator of evidence-informed decision-making and can offer many benefits over single studies, such as having a lower risk of bias and more confidence in results (Petkovic et al., 2018).

Municipal administrations are responsible for preserving, maintaining, and promoting public health. To reduce avoidable environmental risk factors, integrated strategies are recommended with a proactive approach towards emerging issues such as major global trends, new technologies and emerging health threats. In this context, achieving the reduction of emissions and the improvement of quality of life by adapting the City Governance Plan (CGP) is a major challenge for the Municipal Council in Pisa. In the running CGP for 2018–2023 period, the "Environment" dimension is central to all regulatory sectors and occupies a position within the "Quality of life" regulatory area, together with "Green spaces" and "Animal welfare". In the "Environment" dimension, two different policy sectors are defined "Waste" and "Citizens' health", the latter representing a bridge to sectors "Energy", "Mobility", and "Urban planning". The interventions concerning the "Green Spaces" are aimed at improving urban furnishings and recreational activities. It is noteworthy to observe that the evolution of the CGP in Pisa, from 2008 onward, marks a transition of culture and administrative practices towards an environmental policy integration (EPI) framework at the centre of the decision-making process involving different sectoral policies.

To improve the link between scientific evidence and policy actions, a cooperation and research agreement (protocol number 3421/2022) was signed between the Environmental Department of the Pisa municipality and the Institute of Clinical Physiology of the National Council of Research (IFC-CNR), headquartered in Pisa. A knowledge-to-action framework aimed at bridging the gap between research and evidence-informed decision-making was conveniently adopted. It aimed to clarify the environmental risk for human health and ecosystems posed by environmental pollutants and other risk factors in the city and support the evolution of a sustainable vision for city governance. The approach adopted integrates two core components that are both described in this paper: (i) the creation of knowledge through a systematic review to identify, select and critically appraise all the relevant research conducted in Pisa; (ii) the translation of knowledge towards the decision-makers answering to policy-relevant research questions.

2. Materials and methods

2.1. Characteristics of the urban centre of Pisa

The urban centre of Pisa (Tuscany, Italy) is located in a flat region 4 m above sea level and a few kilometres from the mouth of the Arno River, which crosses the city in a flat area surrounded to the east by Monte Pisano mountains (maximum height 917 m). Before the COVID-19 global pandemic, the city was characterised by residential areas and urban/interurban roads, with a population of 91,393 inhabitants as of 2019 (ISTAT, 2022) to which commuters and tourists are added on a daily basis making up more than half of the residents. The population is mainly grouped in residential area districts, ranking among the Italian cities with the highest population density (481 people per sq. km). Some districts are mixed-use, with residential areas and productive or commercial activities (in the historic city centre) and some include important tourist hubs (international airport, railway), cultural (UNESCO site of Piazza dei Miracoli) and university campuses (State University, schools of advanced studies Scuola Superiore Sant'Anna and Scuola Normale Superiore) and hospital hubs (Santa Chiara and Cisanello) occupying significant portions of the city centre. Pisa municipality also includes a portion of the coastal territory in front of the Tyrrhenian Sea (Marina di Pisa), characterised by the strong presence of residential and bathing facilities, densely populated on a seasonal basis, especially in summer. These social dynamics all together affect the daily waste production and the collection's complexity. About 66,877 tons of municipal solid waste (MSW) per year are produced, corresponding to an average of 732 kg/inhabitants per year, a quite high amount if compared to the national average (488 kg/inhabitants) (ISPRA, 2019). The city of Pisa also has a complex structure in terms of constructed areas, rail sections and large roads (such as the Emilia and the Tosco-Romagnola roads). The urban structure largely affects the inhabited centre with a burden of waste, noise, and road traffic. Furthermore, nine industrial plants with AIA (Integrated Environmental Authorization) certification, subject to IPPC permit, contribute to regular or frequent emissions. Some of them are located within the urban fabric (including a plant subject to Seveso), while the others are located in a suburban area (Zona Ospedaletto) mixed with some scattered dwellings. Also, in the extra-municipal area but contiguous to the Pisa shoreline, there is a petrochemical plant whose emissions are at the front line of the municipal administrative boundaries. The city's anthropic footprint adds up to an ongoing climatic transformation. Evidence of climate change effects is reported for the Tuscan coastal line, with a significant increase in the average monthly temperatures by almost 2 degrees during the autumn-winter period, starting from the 90 s (Bartolini et al., 2019).

2.2. Systematic review methodology

We conducted this systematic review using the PRISMA Statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) (Page et al., 2021), and we reported the flow process using the PRISMA flow diagram. Table S1 in the Supplementary Material shows the PRISMA 2020 checklist. Moreover, we used a recent umbrella review on the associations between environmental risk factors and health (Rojas-Rueda et al., 2021) to identify unexplored exposures potentially harmful to human health and verify if our findings are consistent with the existing literature.

2.2.1. Search strategy

We conducted the literature search without search filters on 22 February 2022 in two databases: Medline/PubMed and Embase. We used the keywords Pisa, pollut* , environment* , health, and Pisa syndrome in the following search query: Pisa AND (pollut* OR environment* OR health) NOT Pisa syndrome.

We focused our search on 'Medline/PubMed' and 'Embase', two of the primary international scientific databases in the public health domain. Secondarily, we contacted the corresponding authors of the retrieved publications to ask if other studies on Pisa municipality could be included. Finally, we searched 'Web of Science' and 'Scopus' to limit the loss of different articles without intercepting any new articles.

2.2.2. Inclusion/exclusion criteria

We included all the epidemiological studies that investigated the possible associations between environmental exposures and health outcomes with no language or time restrictions. We also included all studies that analysed the status of environmental pollution in Pisa. We excluded all studies that did not consider environmental pollution and exposure. We also excluded reviews, commentaries, and letters to the editor.

2.2.3. *Study selection*

We imported the search results of the two databases into Rayyan tool for systematic reviews, and we deleted all duplicates detected by Rayyan's algorithm. Two researchers independently screened the titles and abstracts of the retrieved studies based on the inclusion/exclusion criteria. We observed an almost perfect agreement between the two reviewers with a Cohen's Kappa coefficient of 0.803 (Landis and Koch, 1977). Disagreements were resolved through discussion by them. After the initial screening, we searched full texts and screened more in-depth references/articles based on the same inclusion/exclusion criteria to select the articles included in the qualitative Synthesis. The systematic process followed to generate the final list of included articles is summarised in the PRISMA flow chart (Fig. 1). For each step, we reported the number of references/articles identified, included and excluded, and the reasons for exclusions.

2.2.4. *Data collection process*

We labelled each article based on the study focus as environmental monitoring study or environmental health study. The first label refers to studies that assessed the quality of the environment to control the risk of pollution, while the second label refers to studies that investigated the relationships between healthy environments and healthy people. For each study of the environmental monitoring study category, we extracted the following data in Excel: first author and year, the aim of the study, study area, pollutants, environmental matrices, methods, and main results. On the other hand, for each study of the environmental health study category, we extracted the following data: first author and year, the aim of the study, study design, study area, study period, study population, pollutant(s) exposure, health outcome (s), analytical methods, confounding variables, main results.

2.2.5. *Study quality assessment*

We assessed the quality of epidemiological studies using the Newcastle-Ottawa Scale (NOS), which was developed as a collaboration between the University of Newcastle, Australia, and the University of Ottawa, Canada (Wells et al., 2020). The NOS is based on a star scoring system in which a study is judged on three broad perspectives: the selection of the study groups, the comparability of the groups, and the ascertainment of either the exposure or outcome of interest for case-control or cohort studies, respectively. For cohort and case-controls/case-crossover studies, scoring 0–3, 4–6, and 7–10 points were defined as low, moderate, and high quality, respectively. For cross-sectional studies, scoring 0–3, 4–6, and 7–10 points were defined as low, moderate, and high quality.

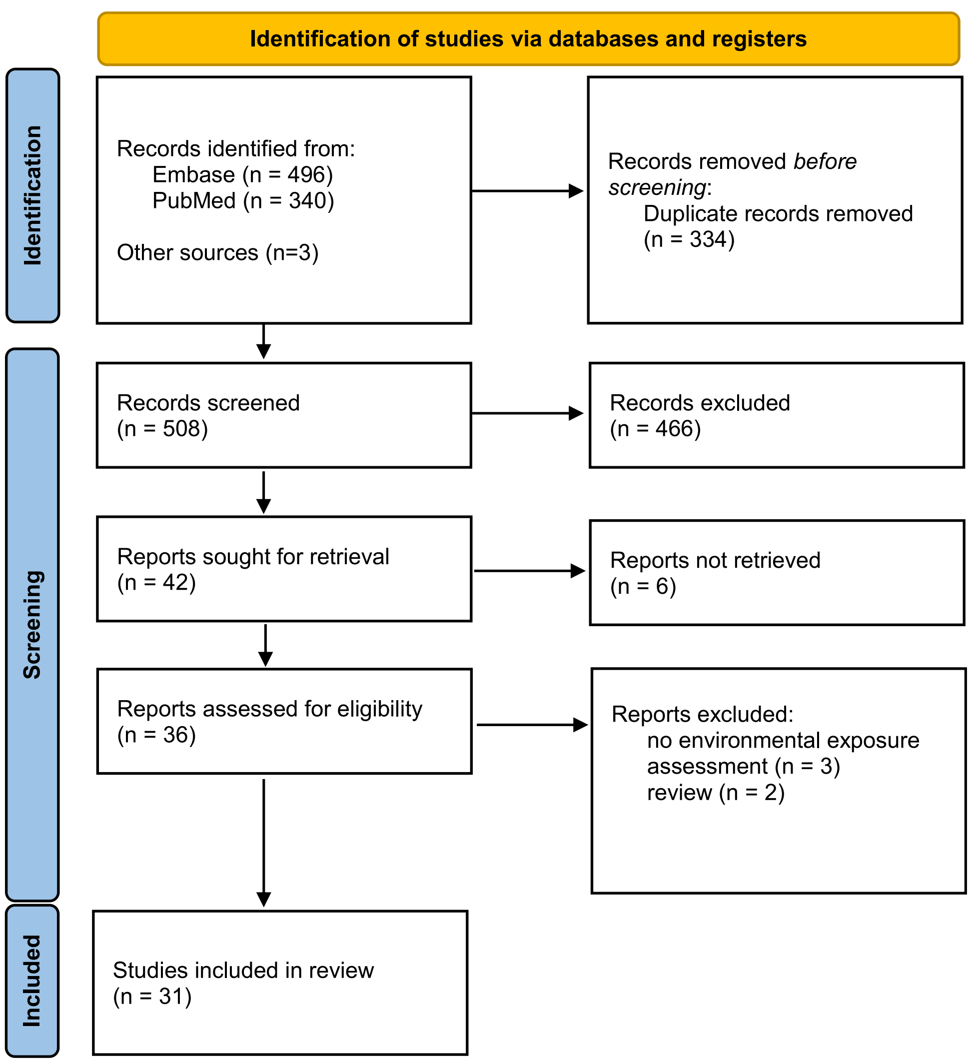

Fig. 1. PRISMA flow diagram.

2.2.6. Synthesis of results

We synthesised the results of the studies, combining them into one of two categories: environmental health study or environmental monitoring study. Within each category, we described the studies in terms of the type of pollutant(s), environmental matrices, study design and health outcome(s) (Verbeek et al., 2012). We did not perform a meta-analysis due to high heterogeneity among studies, specifically in the type of pollutants and the environmental matrices analysed. In each category of studies, a qualitative analysis of results was guided by a set of predefined questions considered relevant for feeding the translational component of the research framework.

2.3. Framework for the narrative-based knowledge translation

A translational cycle approach was developed for the optimal integration of core components in healthcare (Poot et al., 2018). Once the evidence acquired per topic area was synthesised and critically appraised, the extracted data were used to formulate key messages defining a "question set". The questions helped to aggregate data in explanatory textual statements. To put into practice the translation of research evidence tailored to the Pisa administrative context, four questions were answered:

1) What is the evidence on the disease burden in Pisa due to the environmental health determinants?
2) Which features of the urban environment affect the health of citizens?
3) Which environmental risk factors are still unexplored?
4) What is the overall quality of the evidence?

The Environmental Department of the municipality was helpful to co-built the questions identifying topic of concern in the current governing administration to aid framing a new vision for the local Plan.

3. Results

3.1. Creation of knowledge and systematic review

The systematic review was the first component of our research. We identified 31 eligible studies from 508 initial citations screened. Twenty-one of these studies were included in the category *environmental health study*, while the remaining 9 were included in the category *environmental monitoring study*. The full process is depicted in Fig. 1 and the main characteristics of the studies are summarised Table 1 and Table 2, ordered by publication date (newest first).

3.1.1. Environmental health studies

Most studies (16 out of 21) were cross-sectional, while only two were residential cohort studies. The remaining studies were one case-crossover, one time-series, and one time-series/case-crossover study. The sample size varied from 119 subjects living near the railway infrastructure to 132,293 inhabitants of the residential cohort during the followed-up period from 1 January 2001–31 December 2014. The general population was the most common sample in studies (n = 14), followed by adults (n = 5) and children (n = 2). One study investigated a population of children and elderly patients of the emergency room visits for respiratory complaints. The earliest study was published in 1991. There was an overall progressive increase over time; eleven out of twenty-one studies were published (more than 50%) since the beginning of 2010.

A wide range of health outcomes was investigated in the studies included. The most widely investigated type of health outcome was respiratory (n = 14), mainly asthma, rhinitis, chronic phlegm, chronic obstructive pulmonary disease (COPD) diagnosis or emergency visits for respiratory complaints. The second most investigated health outcome was cardiovascular (n = 4). More specifically were investigated the short-term effects of air pollution on cardiovascular hospitalisations, and the effect of noise exposure on systolic and diastolic blood pressure and hypertension. Furthermore, three studies investigated the association between ambient air pollution and early biological health effects, specifically chromosome aberrations (Milillo et al., 1996), buccal micronucleus in children (Villarini et al., 2018) and antibodies anti-BPDE-DNA adduct as indicators of polycyclic aromatic hydrocarbons (PAHs) derived genotoxic damage (Petruzzelli et al., 1998).

The most investigated environmental health risk was air pollution. Seventeen of the 21 studies (about 80%) investigated the relationship between the concentrations of common air pollutants and health. More specifically, the studies considered the following air pollutants: particulate matter less than 10 µm (PM10) and fine particles less than 2.5 µm (PM2.5), nitrogen oxides (NO_x) and dioxide (NO_2), total suspended particulates (TSPs), sulphur dioxide (SO_2), carbon monoxide (CO), ozone (O_3), respirable suspended particles (RSPs). The second most investigated environmental health risk was noise pollution. More specifically, three studies (Petri et al., 2021; Licitra et al., 2016; Ancona et al., 2014) investigated the health effects of noise exposure by measuring the day–evening–night noise level (L_{den}) or the night noise level (L_{night}). Finally, one study investigated the exposure to urban grey spaces as an environmental health risk (Maio et al., 2022). Most of the studies analysed the effect of environmental pollution on the general resident population in the urban area of Pisa. On the other hand, some studies focused on the major sources of environmental pollution in Pisa. More specifically, the remaining studies evaluated the health effect of NO_x exposure to the municipal waste incinerator (MWI) (Romanelli et al., 2019), the noise impact of the railway infrastructure, the health impact of aircraft noise, the impact of different types of noise sources (road, railway, airport and recreational) (Petri et al., 2021; Licitra et al., 2016), and the association between living near one of the main roads (Tosco-Romagnola road) and respiratory health status (Nuvolone et al., 2011). All the studies showed positive associations between air pollution and respiratory and cardiovascular diseases (Table 1). For example, living near one of the main roads of Pisa was associated with an increased risk for respiratory diseases (Nuvolone et al., 2011). Furthermore, Maio et al. (2022) showed an association between increasing exposure to grey spaces coverage and allergic status in an adult general population sample. Regarding noise exposure, all three studies (Petri et al., 2021; Licitra et al., 2016; Ancona et al., 2014) showed some positive association between L_{den} and L_{night} and health outcomes, such as diastolic blood pressure, hypertension, annoyance, and sleep disturbances.

3.1.2. Quality assessment of the health studies

For cross-sectional studies, the methodological quality scores ranged from five to nine points (maximum 10 points). Although fourteen of the sixteen cross-sectional studies scored seven or more points and were considered of high quality (Table 3), we identified some critical points in the methodologies. In our opinion, the samples were always representative of the average in the target population, but in four studies, the sample sizes were not sufficiently justified. Regarding the ascertainment of the risk factors, some studies relied on self-reported exposure information, and they were scored one pont instead of two. Furthermore, two studies did not describe the measurement tool and they were not scored. All studies except two controlled for age and sex, which are considered the most important confounding factors in the NOS scale. The majority of the studies also controlled for additional confounding factors, such as smoking, educational level or body mass index. However, some important confounding factors, such as occupational exposure and deprivation index, were not always included in the analyses. For this reason, the comparability category only gets two stars in four cases. Regarding the assessment of the outcome, most studies relied on self-reported health outcome information, and they were scored one star instead of two. For statistical tests, except for one study, they are always clearly described and appropriate, and the measurements of the associations were

Table 1
Main characteristics of environmental health studies.

First author, year	Study design	Study population	Environmental risk factor	Health outcome (s)	Key findings
(Maio et al., 2022)	cross-sectional	2070 subjects from ages 18–84 years	grey spaces coverage	allergy biomarkers/conditions	A 10% increase in grey spaces coverage was associated with a higher probability of having SPT positivity (OR = 1.07, 95% CI 1.02–1.13), seasonal SPT positivity (OR = 1.12, 1.05–1.19), spolysensitisation (OR = 1.11, 1.04–1.19), allergic rhinitis (OR = 1.10, 1.04–1.17), co-presence of SPT positivity and asthma/allergic rhinitis (OR = 1.16, 1.08–1.25), asthma/allergic rhinitis (OR = 1.06, 1.00–1.12), presence of serum antibodies to BPDE-DNA adducts positivity (OR = 1.07, 1.01–1.14).
(Fasola et al., 2021)	case-crossover	1585 subjects	PM10, PM2.5, NO2, O3	cardiovascular hospitalisations	A 10 μg/m3 increase in PM10 levels (1 km resolution) at lag 0 was associated with cardiovascular shospitalisations (OR = 1.137, 95% CI: 1.023–1.264) during the period 2011–2015. Significant effects at lag 0 during the period 2013–2015 were also found for PM10 (OR = 1.268, 95% CI: 1.085–1.483) and PM2.5 (OR = 1.273, 95% CI: 1.053–1.540) at 1 km resolution, as well as for PM10 (OR = 1.365, 95% CI: 1.103–1.690), PM2.5 (OR = 1.264, 95% CI: 1.006–1.589) and NO2 (OR = 1.477, 95% CI: 1.058–2.061) at 200 m resolution. No significant association was found for O3.
(Petri et al., 2021)	cross-sectional	517 subjects from ages 37–72 years	Lden and Lnight	systolic and diastolic blood pressure	A 5 dB (A) increase of night-time noise was associated with high levels of diastolic blood pressure (DBP) (β = 0.50 95% CI: 0.18–0.81). Furthermore, increased DBP is also positively associated with more noise sensitive subjects, older than 65 years old, without domestic noise protection, or who never close windows. Among the various noise sources, railway noise was found to be the most associated with DBP (β = 0.68; 95% CI: −1.36, 2.72).
(Fasola et al., 2020)	cross-sectional	305 subjects living in Pisa	PM10 and PM2.5	asthma, rhinitis, chronic phlegm, COPD diagnosis	A 1 μg/m3 increase in PM2.5 levels was associated with incidences of rhinitis (OR = 2.25, 95% CI: 1.07–4.98) and chronic phlegm (OR = 4.17, 1.12–18.71). Incidence of chronic obstructive pulmonary disease was associated with PM10: OR = 2.96 (1.50, 7.15)
(Romanelli et al., 2019)	residential cohort	132,293 subjects residing in Pisa	NOx	mortality for all causes and natural causes. Mortality and morbidity for tumours of the lymphohematopoietic system, cardiovascular diseases, and respiratory diseases.	Mortality analysis on males showed increased trends of mortality due to natural causes (HRt p < 0.05), the tumor of the lymphohematopoietic system (HRt p = 0.01), cardiovascular diseases (HRt p < 0.01); in females, increased trends for acute respiratory diseases (HRt p = 0.04). Morbidity analysis showed a HRt for lymphohematopoietic system tumor in males (HRt p = 0.04).
(Maio et al., 2019)	residential cohort	970 subjects aged > 20 years old	vehicular traffic	asthma attacks incidence, allergic rhinitis, COPD	An increase in vehicular traffic exposure (self-reported exposure to vehicular traffic near home) was associated with incidences of rhinitis (OR = 1.8, 95% CI: 1.2–2.8), asthma attacks (OR = 2.2, 95% CI: 1.0–4.5), and COPD (OR = 2.4 95% CI: 1.1–5.2).
(Villarini et al., 2018)	cross-sectional	1318 children (season I), 1149 children (season II) from ages 6–8 years	vehicular traffic	cytogenetic damage (buccal micronucleus)	The micronuclei (MN) frequency in exfoliated buccal cells in children in winter was higher in high-traffic areas (0.43 ± 0.50) than in low-traffic areas (0.49 ± 0.68). Also in the late spring, the MN frequency was higher in high-traffic areas (0.43 ± 0.50) than in low-traffic areas (0.49 ± 0.68).
(Licitra et al., 2016)	cross-sectional	119 subjects, from ages 35–70 years, living around the railway for at least 5 years.	Lden and Lnight	annoyance	The risk of being highly annoyed by railway noise, compared to the reference class (0–50 dB(A)), increases with noise exposure, net of the considered confounding. During daytime, the RR increases from 0.30% at 50–55 dB(A), up to 3.7% over 70 dB(A).

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Table 1 (*continued*)

First author, year	Study design	Study population	Environmental risk factor	Health outcome (s)	Key findings
					Similarly, during night time the risk increases, but less sharply from 0.5% up to 1.3% over 65 dB(A). Almost all the excesses are statistically significant.
(Ancona et al., 2014)	cross-sectional	73.272 subjects residing nearby six airports in Italy (Rome: Ciampino; Milan: Linate and Malpensa; Pisa; Turin; Venice)	Lden and Lnight	hypertension, annoyance, sleep disturbances	Exposure to aircraft noise levels above 55 dB was estimated to be responsible each year of 203.2 (95%CI: 0–438.6) additional cases of hypertension; 408 (95%CI: 285–503) cases of annoyance; 219 (95%CI: 80–457) cases of sleep disturbances.
(Nuvolone et al., 2011)	cross-sectional	2062 subjects living within 800 m of the main road	living within 100 m of the main road	chronic cough (or phlegm), cough (or phlegm), attacks of shortness of breath with wheeze, persistent wheeze, dyspnea, chronic obstructive pulmonary disease (COPD), allergy symptoms, asthma, lung function and skin prick tests.	Compared to subjects living between 250 m and 800 m from the main road, subjects living within 100 m of the main road had increased adjusted risks for persistent wheeze (OR = 1.76, 95% CI: 1.08–2.87), COPD diagnosis (OR = 1.80, 95% CI: 1.03–3.08), and reduced FEV1/FVC ratio (OR = 2.07, 95% CI: 1.11–3.87) among males, and for dyspnea (OR = 1.61, 95% CI: 1.13–2.27), positivity to skin prick test (OR = 1.83, 95% CI:1.11–3.00), asthma diagnosis (OR = 1.68, 95% CI: 0.97–2.88) and attacks of shortness of breath with wheeze (OR = 1.67, 95% CI: 0.98–2.84) among females.
(Vigotti et al., 2010)	case-crossover and time	657 children under ten years and admitted to local hospitals for respiratory diseases (ICD 9: 460–469, 480–519)	PM10, CO, O3, NO2	respiratory diseases (ICD 9: 460–469, 480–519)	A 10 μg/m3 increase in PM10 was associated with an increment of 8.5% (CI 95% 0.02; 17.6) of children's respiratory admissions at lag 0–3. Results were stronger for males and during the warm season. A 1 mg/m3 increase in CO levels was associated with an increment of respiratory admissions at lag 0 (20.2%, CI 95% 5.3; 37.2) and at all cumulative lags: the maximum value was observed at lag 0–3 (32.6%, CI 95% 8.3; 62.2). Time-series analyses provide similar results with lower estimates in terms of percentage increment and length of confidence intervals.
(Maio et al., 2009)	cross-sectional	1602 subjects living in Po Delta and 1.158 in Pisa (from ages 8–74 years)	living in an urban area	bronchial hyperresponsiveness	Living in urban area (Pisa) than a rural area (Po Delta) was an independent risk factor for having bhronchial hyperresponsiveness (OR = 1.41, 95% CI: 1.13–1.76).
(Simoni et al., 2008)	cross-sectional	1946 subjects living in Po Delta, 2064 in Pisa	living in an urban area	current asthma, chronic bronchitis/ emphysema (COPD), COPD/chronic cough/ chronic phlegm (COPDsx), spirometric tests	Higher prevalence of COPD, COPDsx, and asthma in the urban than in the rural area.
(Vigotti et al., 2007)	time series	966 patients: 533 children and 433 elderly	PM10, NO2, CO	emergency visits for respiratory complaints	A 10 μg/m3 increase in PM10 levels was associated with an increase in emergency visits of 10% (95%CL: 2.3;18.2) in children. An increase of 11.8% (95%CL:1.4;23.3) was also observed for NO2. A 10 μg/m3 increase in PM10 levels was associated in emergency visits of 8.5% (95%CL:1.5;16.1) in the elderly. Moreover, a 1 mg/m3 in CO levels was associated with an increment of 26.5% (95%CL: 3.4;54.8).
(Simoni et al., 2004)	cross-sectional	1090 subjects > 15 years old	NO2 and PM2.5	acute respiratory illnesses with fever, bronchitis/asthmatic symptom, peak expiratory flow (PEF) form maximum amplitude and for diurnal variation	Prevalence rates of acute respiratory symptoms were significantly higher in the urban than in the rural area. Acute respiratory illnesses with fever were significantly associated with indices of NO2 (odds ratio (OR = 1.66; 95% CI: 1.08–2.57) and PM2.5 exposures (OR = 1.62, 95% CI: 1.04–2.51), while bronchitic/asthmatic symptoms were associated only with PM2.5 (OR = 1.39, 95% CI: 1.17–1.66). Peak expiratory flow variability was positively related only to PM2.5 exposure index (OR= 1.38, 95% C: 1.24–1.54, for maximum amplitude; (OR = 1.37, 95% CI: 1.23–1.53, for diurnal variation).
(Simoni et al., 2003)	cross-sectional	428 subjects living in Po Delta, 761 in Pisa	NO2, RSPs, and ETS	acute respiratory symptoms	The occurrence of acute respiratory symptoms was consistently higher in relation to the high respirable suspended particles-index exposure compared to low exposure (33 versus 27% in winter, 27 versus 21% in

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Table 1 (*continued*)

First author, year	Study design	Study population	Environmental risk factor	Health outcome (s)	Key findings
					summer). Both the presence of environmental tobacco smoke at home and exposure to the high respirable suspended particles-index were associated with a decrease in the mean daily peak expiratory flow.
(Viegi et al., 1999)	cross-sectional	2136 subjects living in the Po Delta, 2257 in Pisa	TSPs and SO2	cough, phlegm, wheeze, attack of wheeze, dyspnea	Prevalence rates (%) of respiratory symptoms tended to be higher in urban than in rural areas.
(Petruzzelli et al., 1998)	cross-sectional	825 subjects living in the suburban area of Cascina, 520 in Pisa	living in an urban area	the presence of serum antibodies anti-BPDE-DNA adduct as indicators of polycyclic aromatic hydrocarbons (PAHs) derived genotoxic damage	Excess prevalence of anti-BPDE-DNA antibody positivity in people living in the urban area (OR, 1.49; 95% CI, 1.16–1.92);
(Baldacci et al., 1997)	cross-sectional	2136 subjects living in Po Delta, 2841 in Pisa	living in an urban area	slow vital capacity, CO single-breath diffusing capacity, single-breath nitrogen test, and forced expirograms	Prevalence rates (%) of respiratory symptoms tended to be higher in urban than in rural areas.
(Milillo et al., 1996)	cross-sectional	60 subjects living in Po Delta, 134 in Pisa and 116 in Cascina.	TSPs and SO2	chromosome aberrations	The frequency of chromosome aberrations in Pisa was statistically significantly higher than that of the Po Delta. In addition, respiratory symptoms used as indirect indicators of air pollution at the individual level were significantly more frequent in the Pisa population than in Cascina or in the Po Delta.
(Viegi et al., 1991)	cross-sectional	3289 aged 8–64 living in the Po Delta and 2917 living in Pisa	TSPs and SO2	chronic cough (or phlegm), coughing (or producing phlegm), wheeze, attacks of shortness of breath with wheeze (SOBWHZ), dyspnea, rhinitis, hay fever, other allergies, emphysema, chronic bronchitis, asthma, tuberculosis, pleuritis, and abnormal chest X-ray.	Living in an urban area (Pisa) than a rural area (Po Delta) was an independent risk factor for having rhinitis (OR = 4.0, 95% CI: 3.7–4.3) and wheeze (OR = 2.8, 95% CI: 2.6–3.0)

presented, including confidence intervals and probability levels. On the other hand, the two cohort studies and the two case-crossover studies were considered high-quality studies and they were scored with eight out of nine stars because they did not consider the occupational exposure as a potential confounder. Despite this limitation, these studies considered as health outcomes the mortality and hospital discharge records, which increases the reliability of data.

3.1.3. Environmental monitoring studies

We observed an overall progressive increase over time; seven out of nine studies (about 75%) were published since the beginning of 2010. Air was the most investigated environmental matrix, with four out of nine studies. This environmental matrix was investigated to evaluate both air pollution and noise pollution. The second most investigated environmental matrix was soil, followed by one study on the sand and one on fresh and seawater. The most investigated pollutants were heavy metals. The earliest study was published in 1985 and assessed the Cu, Pb, Cd and Cr concentrations in sampling stations along the river Arno and its plume. The levels of Cu, Pb and Cd were higher than in the reference station and the minimal risk concentration was exceeded for Cd (Betti et al., 1985). The presence of trace metals in the soil was investigated in several areas of Pisa. More specifically, one study assessed the concentrations of Pb, Cu, Ni, Cd, As, Hg, Cr and Zn in the pedological environment of the area near the MSWI of Pisa, showing an increase in Pb and Zn concentrations coming from environmental pollution (Bretzel and Calderisi, 2011). Another study analysed the concentrations of Cr, Cu, Mn and Zn together with dandelion shoots and root tissues, showing very limited soil pollution due to trace metals in the urban sites, except for the Zn concentrations in root tissues that sometimes reached the limits of toxicity (Vanni et al., 2015). A more recent study assessed the quality of 31 urban soils in Pisa by analysing total petroleum hydrocarbons (TPHs), Cd, Cr, Cu, Hg, Mn, Ni, Pb, Zn, and the platinum group elements (PGEs). More than 50% of the areas in Pisa showed TPH values in the range of 100 and 150 mg/kg (the legal limit is set to 60 mg/kg), indicating widespread and intense pollution throughout the entire city (Cardelli et al., 2017). The second most investigated pollutant was airborne particulate matter, with the earliest study published in 1997 with the aim to investigate the levels of airborne particles in different areas in Pisa and to study the genotoxic activity using TA98 and TAI00 strains of Salmonella typhimurium. The results showed that the higher mutagenic effect was always found in the area near a street with intense and slow traffic (Bronzetti et al., 1997). Another study, which investigated the air levels of PM10, PM2.5, NO2, and O3, highlighted that the PM10 daily limit value of 50 mg/m3 was exceeded more than 35 times for a year (Gandini et al., 2013). A more recent multicentric study, the MAPEC_LIFE study, collected the following particle size fractions: 10.0–7.2, 7.2–3.0, 3.0–1.5, 1.5–0.95, 0.95–0.49, and < 0.49 mm (PM0.5). The chemical composition and mutagenic and genotoxic effects induced by PM0.5 were evaluated in five Italian towns near several primary schools. The highest concentrations of PAHs and nitro-PAHs were observed in Pisa samples in winter. Moreover, BEAS-2B cells showed light DNA damage in Pisa samples in winter (Bonetta et al., 2019). One more recent study assessed the abundance and composition of microplastics and mesoplastics on a sandy beach of the Migliarino San Rossore Massaciuccoli Nature Park, showing average concentrations of 207 ± 30 MPs/kg d.w., and 100 ± 44 MEPs/kg d.w., respectively. Seasonal changes in the flow of the Arno River, industrial activities, and urban footprint were considered the major sources of plastic pollution (Scopetani et al., 2021). One study also investigated the exposure noise levels generated by different sources, showing a greater annoyance for aircraft noise and smaller for railway noise (Licitra and Ascari, 2014).

3.2. Narrative-based knowledge translation

The core translational knowledge was operationalised using a narrative synthesis of the systematic review results by answering four questions highlighting the concerns of the political administration. The findings were further disseminated through the institutional website of the municipality with a layman's report written in Italian (https://www.

Table 2
Main characteristics of environmental monitoring studies.

First author, year	Study area	Pollutants	Environmental matrix	Main results
(Scopetani et al., 2021)	Beach of the Nature Park of Migliarino San Rossore Massaciuccoli (Pisa, Italy).	Mesoplastics (MEPs) and microplastics (MPs)	Sand	Meso- and microplastics were detected in all samples with average concentrations of 207 ± 30 MPs/kg d.w., and 100 ± 44 MEPs/kg d.w., respectively. Seasonal changes of flow of the Arno River, industrial activities, and urban footprint were considered as the major sources of plastic pollution.
(Bonetta et al., 2019)	Schools in five Italian cities. Torino and Brescia located in the Padana Plain in the north of Italy (one of the most polluted areas in Europe), Pisa and Perugia in central Italy (medium- low pollution area) and Lecce in southern Italy (low pollution area)	PM10, PM0.5, PAH and nitro-PAH	Air	PM10 in Pisa was lower than the EU daily limit value of 50 mg/m3. A significant decrease in PM10, PM0.5, PAH and nitro-PAH was observed from winter to spring. PM0.5 in Pisa represented a high proportion of PM10, accounting for 43% in winter and 33% in summer. Regarding four S. typhimurium strains, low mutagenic activity was observed. Overall, no genotoxic effect of PM0.5 was observed using the A549 cell line. The comet assay showed a greater genotoxic effect of PM0.5 extracts in winter samples. No chromosomal damage was observed using the CBMN test.
(Cardelli et al., 2017)	31 sites around the urban areas of the city of Pisa.	Total petroleum hydrocarbons (TPHs), Cd, Cr, Cu, Hg, Mn, Ni, Pb, Zn, and the platinum group elements (PGEs).	Soil	Very few areas showed TPHs under the legal threshold of 60 mg/kg, according to general findings indicating that roadside (traffic) and industrial areas are important emission sources of TPHs. The Igeo indicated no Cd, Cu, Mn, Ni, and Zn pollution and minimal Pb and Cr pollution due to anthropogenic enrichment. The Pt and Pd amounts were below the detection limits in 75–90% of the urban soils, with the greatest amounts in sites located at junctions with dense traffic.
(Vanni et al., 2015)	31 sites around the urban areas of the city of Pisa.	Heavy metals (Cr, Cu, Mn, and Zn)	Soil	The results showed a widespread but very limited soil pollution of trace metals in the urban sites. According to Igeo and EF indexes, approximately 90% of the monitored sites showed a low level of Cr pollution, while the remaining soils were classified as moderately polluted. Regarding Cu, urban soils showed an Igeo of 0.40, typical of unpolluted areas. However, the EF value of 1.55 indicated an anthropogenic enrichment, and also the PI revealed that pollution was moderate and widespread. For Mn, both Igeo and EF classifications showed no enrichment or soil pollution by Mn, while PI showed a medium-low pollution level.
(Licitra and Ascari, 2014)	European cities.	Environmental noise	Air	From the comparison, it is evident that areas affected by railway noise decrease their rating and aircraft ones raise, that is coherent with the annoyance assumptions, considering a greater annoyance for aircraft noise and smaller for railway noise.
(Gandini et al., 2013)	Milan, Mestre-Venice, Turin, Bologna, Florence, Pisa, Rome, Taranto, Cagliari, Palermo, Treviso, Trieste, Padua, Rovigo, Piacenza, Parma, Ferrara, Reggio Emilia, Modena, Genoa, Rimini, Ancona, Bari, Naples and Brindisi.	PM10, PM2.5, NO2 and O3	Air	A decrease in PM10 and PM2.5 was observed from winter to spring. For PM10, the EU daily limit value of 50 mg/m3 was exceeded more than 35 times for a year. The annual averages of 40 μg/m3 for PM10, 25 μg/m3 for PM2.5 and 40 μg/m3 for NO2 were respected for the whole period. The long-term trends showed a decrease in annual average NO2 concentrations.
(Bretzel and Calderisi, 2011)	A MSWI located in the peri-urban area of Pisa, Italy. The area surrounding the MSWI is located within a network of very busy roads that lead to the city and includes agricultural activities and light industries.	Heavy metals (Pb, Cu, Ni, Cd, As, Hg, Cr and Zn).	Soil	The results of this study showed that the main pollutants in the area around the MSWI plant in Pisa were lead and zinc. Other metals such as As, Cr and Ni were present as background-origin. The direction of the prevailing wind influenced the distribution of (Pb and Zn, but the distance from the point source had no effect on the distribution of the pollutants.
(Bronzetti et al., 1997)	Three different urban areas: an area near a street with intense fast moving traffic (site I), an area near a street with intense and slow traffic (site 2) and an area near the historical centre where road traffic is limited (site 3).	Airborne particles	Air	The results show a cyclic trend of mutagenicity, statistically significant, during the year: lower in the summer, higher in the winter. These results confirm the importance of periodic repeated sampling during the year to obtain complete information about the pollution and the mutagenicity of an area.

(*continued on next page*)

Table 2 (*continued*)

First author, year	Study area	Pollutants	Environmental matrix	Main results
(Betti et al., 1985)	Tyrrhenian Sea in front of S. Rossore Park.	Heavy metal (Cu, Pb, Cd and Cr)	Fresh and sea water	The content of Cu, Pb and Cd was always found to be higher than in the reference station (about 8 km offshore), generally reaching maximum values around the mouths of the rivers. Concentrations exceeding the minimal risk concentration were observed in the case of Cd. As for Cr, its concentration was always below the detection limit of the analytical method used. Rivers thus appear to be the main sources of coastal metal pollution.

comune.pisa.it/it/ufficio/stato-fattori-di-rischio-ambientale) and, stemming from the report analysis, a new vision for the local Plan was proposed to the Environmental Department manager to feed the next CGP.

3.2.1. *New vision for susustainable urban development in Pisa*

The most important environmental risk factors associated with the urban characteristics of Pisa were air and noise pollution. According to the European Environment Agency, air pollution is the major cause of premature death and disease in Europe (Bretzel and Calderisi, 2011). Although the levels of air pollutants in Pisa are medium between most polluted cities of North Italy and the lower northern Europe cities (Khomenko et al., 2021), the excess mortality and morbidity rates from cardiovascular and respiratory diseases was not negligible in the municipality and groups potentially more vulnerable, such as children and people over the age of 65, should be protected. Regarding noise pollution, exceeding safe levels is produced singularly or more frequently by the combination of different sources, such as traffic and railway noises or airport movements. Noise exposure was particularly relevant for subjects in the community categorised as highly noise-sensitive (Abbasi et al., 2021) and showing the highest perception of noise. Furthermore, the mediation effect of air pollution on the relation between noise exposure and hypertension and CVDs is still unclear and represents an important avenue for future research. Exacerbating conditions for CVDs in medium-polluted urban cities include extreme heat events and limited residential greenness, which represents an unfavourable condition for reducing air pollution, noise, temperature and urban heat island effect.

The impact of the urban environment reported for the citizen's health suggests that the "Quality of life" regulatory area in the next CGP of the Pisa municipal Council should add measurable goals for the improvement of greenness, considering the density of inhabitants and neighbourhoods linking them with critical health indicators as emerged from the present systematic review (Bikomeye et al., 2021). In particular, consistent scientific evidence demonstrated that green spaces can improve air quality and reduce noise in cities (Abbasi et al., 2021). Green areas could also be instrumental to air pollution mitigation and coping with advancing climate warming, which is extremely important given the urgency to take climate change mitigation and adaptation steps (Son et al., 2021). Based on our findings, Green Spaces and Citizen Health dimensions in the CGP should be connected to each other (Fig. 2), as there is growing evidence that policy actions aimed at increasing the green areas offer a variety of mental, physical and social benefits for humans (van den Berg et al., 2015). Similarly, Wastes and Citizen Health dimensions were reported to be strongly connected in the retrieved literature (Romanelli et al., 2019) and should reinforce reciprocal relations, e.g., quantifying the health benefits derived from the adoption of a waste management sustainable approach, and fast achieving the goal set by the national regulation for the separate collection of the urban wastes.

4. Discussion

The evidence-based knowledge is recurrently being applied to decision-making as an aid in the decision-making process when interventions are to be taken to be beneficial for the city's sustainability (Hailemariam et al., 2019). Some approaches have been proposed based on case studies applications, while how to put into practice the translation of evidence is still challenging (Poot et al., 2018). We demonstrated how scientific evidence could support tailored intervention to the local context by simultaneously adopting tools for knowledge creation and developing key messages for decision-makers. As for the use of systematic reviews in local government public health, it is an important tool that can guide policy-makers to be more reflective of the decisions facing local authority public health teams (South and Lorenc, 2020).

Specifically, in our research, a systematic review was carried out for the first time on the urban environment and health of an Italian city with a wide scope of supporting the adoption of an EPI framework (European Environment Agency, 2022). The systematic review found 21 out of 31 studies addressing the associations between environmental risk factors and human health and 9 out 31 assessing the contamination of the environmental matrices. Prevalently, the studies showed positive direct associations between exposure to urban air and noise pollution and health effects and an indirect impact on the built environment.

4.1. *Air and noise pollution*

Overall, since the 1990 s, the prevalence of respiratory outcomes (especially asthma, rhinitis and COPDs) has been increasing in the adult population of Pisa (Maio et al., 2016). In those years, the urban area of Pisa already showed significantly higher levels of pollution than rural areas of Po Delta and worse respiratory outcomes (Maio et al., 2009; Simoni et al., 2008, 2003; Viegi et al., 1999; Baldacci et al., 1997; Viegi et al., 1991). Specifically, for the observation period between 1991 and 2011, an increase of 37.4% was observed for allergic rhinitis. Studies comparing rural and urban communities were based on epidemiological techniques that were very common in the past and outdated in recent years (Galea and Vlahov, 2005). Exposure to atmospheric pollutants of anthropogenic origin (PM10, PM2.5, NO2, CO, SO2, O3, TSP, PAH) could therefore be considered chronic, although there decreasing trend for NO2 has been generally reported for the Italian cities (Cardelli et al., 2017). Furthermore, early biological effects measured in humans and bacteria (children and Salmonella, respectively) confirmed cytotoxic damage from atmospheric pollution exposures with a worsening in winter. In particular, for the inhabitants who live along road sections with heavy traffic a worst respiratory health was confirmed (Bonetta et al., 2019). Some authors found that a change of 1 $\mu g/m^3$ in the annual average of fine particulate matter levels was associated with an increase of about 200%, 300% and 400% for the risk of rhinitis, COPDs and chronic phlegm, respectively (Romanelli et al., 2019). Furthermore, exposure to NO2 was associated with an increase of 6% in cardiovascular risk in the general population (Romanelli et al., 2019), while an increase of 10% in PM10 levels can cause an increase of 13% in

Table 3
Assessment of the quality of studies by using the Newcastle-Ottawa Scale.

Cross-sectional studies

First author, year	Selection				Comparability (up to 2 stars)	Outcome		Score
	Representativeness of the sample	Sample size	Non-respondents	Ascertainment of the exposure/risk factor (up to 2 stars)	Comparability of subjects on the basis of the design or analysis	Assessment of outcome (up to 2 stars)	Statistical test	
(Maio et al., 2022)	*	*	*	* *	* *	*	*	9/10
(Petri et al., 2021)	*	*	*	* *	*	* *	*	9/10
(Fasola et al., 2020)	*		*	* *	*	*	*	7/10
(Bonetta et al., 2019)	*		*	* *	*	* *	*	8/10
(Licitra et al., 2016)	*	*	*	* *	*	*	*	9/10
(Ancona et al., 2014)	*	*	*	* *		*	*	7/10
(Nuvolone et al., 2011)	*	*	*	*	* *	*	*	9/10
(Simoni et al., 2008)	*	*	*		* *	* *	*	8/10
(Maio et al., 2009)	*	*	*		*	* *	*	7/10
(Simoni et al., 2004)	*	*	*	* *	*	* *	*	8/10
(Simoni et al., 2003)	*	*	*	* *	*	* *	*	8/10
(Viegi et al., 1999)	*	*	*	*	*	*	*	7/10
(Petruzzelli et al., 1998)	*		*	*	* *	* *	*	8/10
(Baldacci et al., 1997)	*	*	*			* *		5/10
(Milillo et al., 1996)	*		*		*	* *	*	6/10
(Viegi et al., 1991)	*	*	*	*	*	*	*	7/10

Cohort study

First author, year	Selection				Comparability (up to 2 stars)	Outcome			Score
	Representativeness of the exposed cohort	Selection of the non-exposed cohort	Ascertainment of exposure	Demonstration that outcome of interest was not present at start of study	Comparability of cohorts on the basis of the design or analysis	Assessment of outcome	Was follow-up long enough for outcomes to occur	Adequacy of follow up of cohorts	
(Romanelli et al., 2019)	*	*	*	*	*	*	*	*	8/9
(Maio et al., 2019)	*	*	*	*	*	*	*	*	8/9

Case-crossover studies

First author, year	Selection				Comparability (up to 2 stars)	Outcome			Score
	Is the case definition adequate?	Representativeness of the cases	Selection of Controls	Definition of Controls	Comparability of cases and controls on the basis of the design or analysis	Ascertainment of exposure	Same method of ascertainment for cases and controls	Non-Response rate	
(Fasola et al., 2021)	*	*	*	*	*	*	*	*	8/9
(Vigotti et al., 2010)	*	*	*	*	*	*	*	*	8/9

hospitalisations (Fasola et al., 2021). In addition, for every 10 μg/m^3 increase in PM10 an increase of 85% was observed in access to the emergency room for respiratory problems in children during the three days following a peak in the air (Vigotti et al., 2007).

The second most investigated environmental risk factor in Pisa was noise pollution. Consistently with previous literature, which reported significant correlations between noise exposure and hypertension, annoyance and sleep disturbance (Münzel et al., 2014), several studies carried out in Pisa showed positive associations between exposure to noise and health effects (Petri et al., 2021; Licitra et al., 2016; Ancona

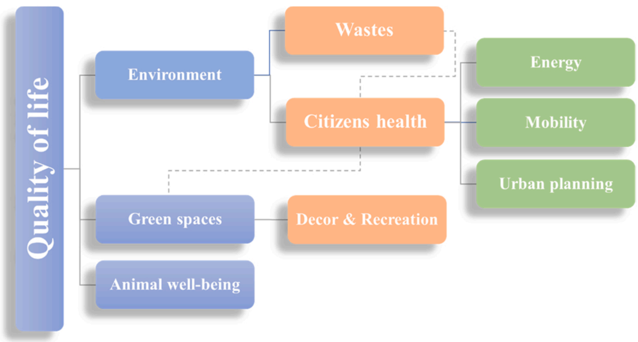

Fig. 2. Block diagram linking the regulatory areas of the running CGP (2018–2023) with "Citizen health". Dashed lines represent under-exploited pathways to improve the "Quality of life" domain.

et al., 2014). Specifically, it was estimated that every year in Pisa, about 201 cases of hypertension, 219 of sleep disturbance and 408 of annoyance were due to airport noise above 55 dB. In particular, the number of annoyed subjects increases between 0.3% and 3.7% for noise ranging from 50 dB to over 70 dB. It was also confirmed that annoyance has an increasing trend as the noise level increases, showing a greater increase during the day than at night (Licitra et al., 2016). Moreover, an increase in blood pressure, which represents a prognostic indicator of hypertension and cardiovascular diseases, was found for the increase of only 5 dB at night (Petri et al., 2021). Households that do not adopt protective behaviours (such as closing windows or applying noise barriers) suffered from the worst impact, mostly reported by people over the age of 65. Among the various sources that simultaneously contribute to noise in the city, exposure to railway noise was most responsible for the altered diastolic pressure at night and mainly in the residential urban area close to the railway station handling area (Petri et al., 2021).

4.2. Built environment impact

An increase of up to 10% in cemented areas in the surrounding urban environment around one's residence was associated with a high probability of being allergic or having asthma (Maio et al., 2022). Indeed, accumulating evidence indicates that the characteristics of urban green spaces are associated with numerous beneficial effects, such as the reduction of exposure to air pollutants, noise and excess heat and increased physical activity (WHO, 2016). Also, the residential greenspace has beneficial effects on childhood development by reducing the adverse developmental effects mediated by traffic and noise exposures (Liao et al., 2019; Jarvis et al., 2021). Some peri-urban areas in Pisa were characterised by pollution mainly attributable to point sources of industrial origin due to the presence of an incinerator operating until 2018 (Bretzel and Calderisi, 2011), or under the influence of the nearby petrochemical area of Leghorn (Romanelli et al., 2019). The quality of the urban environment was also significantly impacted by the ubiquitous presence of the city soil hydrocarbons above the regulated levels (Cardelli et al., 2017). This contamination was representative of the intense use of fuel engines. Instead, more reassuring medium-low values were measured for metals in the urban soils (Cardelli et al., 2017; Vanni et al., 2015) though copper, lead and cadmium were found in one study in the fresh water at the Arno River mouth, and only the cadmium exceeded the risk level (Betti et al., 1985). Interventions aiming at increasing sustainable mobility have been approved by the City Council in the year 2020 to contain atmospheric pollution and reduce the depositions on the ground, and limit direct contamination from traffic (Municipality of Pisa, 2023). A definitely "modern" pollutant emerging in various urban areas of the world was also found in Pisa, represented by meso- and microplastics contaminating at high concentrations both the water of the Arno River and the coastal sands facing the natural reserve of San Rossore-Massaciuccoli, yet not involved in tourism activities (Scopetani et al., 2021).

4.3. Comparison with the umbrella review

Comparing our findings with existing research on the urban health impact assessment issue recently summarised in an umbrella review (Rojas-Rueda et al., 2021), we identified several environmental risk factors still unexplored in Pisa. One of these is the association between environmental noise exposure and diabetes. Although in Pisa noise exposure was associated with several health effects (Petri et al., 2021), no studies investigated the potential relationship with diabetes. Furthermore, the umbrella review reported significative association of heatwaves with cardiovascular and respiratory mortality in adults and elderly populations. Specifically, a heat increment by one unit of measurement was related to acute illness, including heart failure, CVDs mortality, diabetes, respiratory disease, and respiratory mortality (Rojas-Rueda et al., 2021). As for future research, it would be interesting to investigate the health effects associated with the increasing temperature trend reported for the Tyrrhenian coastal area of Tuscany near Pisa (Bartolini et al., 2019), considering the effect of improving urban greenness as a protective factor.

4.4. Limitations and knowledge gaps

Our systematic review retrieved a high heterogeneity among studies regarding different epidemiological study designs, study populations, exposures assessment and outcomes. Shortcomings emerging from the analysis include an incomplete and not updated availability of environmental data, representing the primary need to advance the SDGs and ensure that environmental concerns are considered in all policy sectors. Currently, the acquisition of highly representative data distinguishes a "modern" study, which is based on high-level technologies for measurements and computation of "big data" (Vigotti et al., 2007). More use of mobile sensors and data from environmental networks with high spatial resolution and personal mobile devices represents the new target for environmental epidemiology (Liao et al., 2019). The quality assessment of the studies highlighted the risk of bias in each study, providing suggestions for the quality improvement of future research. Specifically, most studies adopted a cross-sectional design in which all the information refers to the same point in time. Cross-sectional studies are snap-shots of the population status concerning disease or exposure variables, or both, at a specific time (Galea and Vlahov, 2005). Although sometimes cross-sectional information can be considered a good proxy for longitudinal data (Münzel et al., 2014), future research in Pisa should focus on longitudinal studies that are generally more informative concerning causal hypotheses. Despite this limitation, in line with rapid advances in methods and approaches to the epidemiology of the 21st century (WHO, 2016), we observed an improving tendency in the epidemiological studies carried out in Pisa, with a more accurate assessment of individual exposure, for example, by using atmospheric dispersion modelling and geographical information systems (Petri et al., 2021; Fasola et al., 2020; Vigotti et al., 2007; Viegi et al., 1999). However, the consideration of existing environmental protective factors and of vulnerable and disadvantaged populations should be improved in next-generation studies to provide effective and locally adapted intervention measures. Furthermore, to reduce heterogeneity, it is recommended to define the health outcomes and risk effect estimates, adopting recognisable categories and effect measures to allow external comparisons of evidence over time and different geographical locations (ISTAT, 2022). The assessment of the quality of evidence highlighted that the social deprivation of the residents was defined using heterogeneous approaches and was not available by neighbourhood or other homogeneous areas in Pisa. This information is required to reduce the uncertainty in the causality of the estimated associations between disease and the risk factor. Moreover, the production of annual or biennial health profiles for the Pisan population and its subgroups, by disease and year, would be an important tool to greatly improve the quality of studies and allow for monitoring and evaluations of impacts of ongoing and future transformations due either to government policy interventions and climate changes (Maio et al., 2022; Bronzetti et al., 1997). In specific cases, the richness of information on confounding (e.g., occupational or behavioural) reinforced the study conclusions (Fasola et al., 2021). On the other hand, the environmental contamination from emerging pollutants like micro- and meso- plastics in various town locations highlighted the need for future research to monitor plastic pollution levels and assess health risks. Ingestion by the food chain is the principal route of exposure (Sánchez et al., 2022), but recently microplastics have even been found in the air and in indoor dust (Munyaneza et al., 2022; Zhang et al., 2020). The knowledge of the health effects due to microplastic exposure is still limited, but there is evidence that the high surface area of microplastics may lead to oxidative stress, cytotoxicity and translocation to other tissues (Prata et al., 2020) evocative conditions for different NCDs. More generally, current trends of urban health impact assessment (HIA) research cover the issue of human health risks by toxic elements mainly represented by heavy metals and hydrocarbons in urban soil and dust in 2012–2021 (Luo et al., 2022). These studies lay the foundation for future research to investigate the potential human health risks in Pisa, where widespread and intense pollution was observed.

5. Conclusions

Our research aimed at supporting the development of a sustainable vision for city governance adopting a knowledge-to-action framework. In the first phase, we conducted a systematic review to synthesise all the available evidence on health risks and identify vulnerable population groups. For the first time, a systematic review examined the global status of environment and health and their relationship in the municipality of Pisa, identifying some of the most significant risks and current knowledge gaps and challenges. The second phase aimed to raise institutional awareness about air and noise pollution and emerging pollutants that could have harmful effects on humans and the ecosystem. Also, the results suggested that future research should investigate the health effects associated with temperature in Pisa, considering that urban greenness could represent a protective factor for NCDs. Comparing our findings with a recent umbrella review on environmental risk factors and health, we identified other determinants still unexplored in Pisa, such as the association between environmental noise exposure and diabetes. Furthermore, the levels of microplastic in water and sand and hydrocarbons in urban soil appeared critical for the environment and potentially for the exposed community.

Although an EPI framework is increasingly discussed as a preferred strategy to deal more effectively with complex and multiple policy domains affecting health, our findings highlighted that existing silos in city governance remain a barrier to the effective integration of data and environmental sustainability goals achievement across policy sectors. For this reason, we recommended that the City council of Pisa should adopt the following actions:

1. Develop a city health profile and related data on the living environment (e.g., air and noise pollution levels, electromagnetic field levels, warmer temperatures, water quality, green space coverage) and other health determinants (e.g., socioeconomic deprivation). It should represent a lively tool to monitor trends and emerging risks not captured in this systematic review. It also could aid the quantification of health impacts of urban policies at different stages of the policy process;
2. Develop a Strategical Plan to identify targets within the SDGs 11 and 3 and measure the progress of the CGP of Pisa on population health indicators and health inequalities;
3. Develop a collaborative network among researchers, policy-makers, local authorities, community representatives and practitioners to empower the leadership of the Environmental Department in urban resilience management. Other policy areas, such as economic, development, transport, energy, fisheries and agriculture, should connect with each other's enabling a horizontal working cooperation.

CRediT authorship contribution statement

Nunzia Linzalone: Conceptualization, Methodology, Software, Data curation, Writing – original draft, Visualization, Investigation, Supervision, Software, Validation, Writing – review & editing. **Gabriele Donzelli:** Methodology, Software, Data curation, Writing – original draft, Visualization, Investigation, Validation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

No data was used for the research described in the article.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.envsci.2023.05.009.

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